SENSORIMOTOR ADAPTATION FOLLOWING EXPOSURE TO AMBIGUOUS INERTIAL MOTION CUES

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INTRODUCTION

The central nervous system must resolve the ambiguity of inertial motion sensory cues in order to derive accurate spatial orientation awareness. We hypothesize that multi-sensory integration will be adaptively optimized in altered gravity environments based on the dynamics of other sensory information available, with greater changes in otolith-mediated responses in the mid-frequency range where there is a crossover of tilt and translation responses. The primary goals of this ground-based research investigation are to explore physiological mechanisms and operational implications of tilt-translation disturbances during and following re-entry, and to evaluate a tactile prosthesis as a countermeasure for improving control of whole-body orientation.

METHODS

Tilt-Translation Adaptation: During this past year we examined the effects of stimulus frequency on adaptive changes in eye movements and motion perception during combined tilt and translation motion profiles. The Tilt-Translation Sled was developed to provide tilt stimuli during which the resultant gravitoinertial force (GIF) remains aligned with the longitudinal body axis, thus resulting in a mismatch in which the canals and vision signal tilt while the otoliths do not. Using this “GIF aligned’ paradigm, 14 subjects were tilted within a lighted enclosure that simultaneously translated at one of 3 frequencies for up to 30 min. The tilt and translation profiles were restricted to one plane at a time to compare adaptation when using either pitch tilt with fore-aft translation (0.15, 0.3 and 0.6 Hz) or roll tilt with lateral translation (0.3 Hz only). During one session, subjects actively pitched their heads at 0.3 Hz concomitantly during sled translation using visual feedback of desired and actual head position. Changes in perceptual tilt responses were determined by comparing pre- and post-adaptation runs performed in darkness. Adaptive changes in manual control were also evaluated during closed-loop tilt nulling task in complete darkness, both with and without vibrotactile feedback of tilt error. Changes in spatial cognitive function during vestibular adaptation were assessed with 3D mental rotation, match-to-sample and combined tasks using cube assemblages.

Tactile cueing as a gravitational substitute during parabolic flight: An additional Education Outreach project was scheduled during parabolic flights in January 2009. This experiment will examine how spatial awareness is affected during the microgravity phase of parabolic flight, and how vibrotactile cueing of spatial vertical can be used to substitute for altered gravity-receptor input. During the flight, subjects will sit in a tilted chair that will be used to change their orientation relative to the floor. Subjects will be asked to memorize the location of different targets located around the chair that will be later presented on a light-weight video mask in the absence of other visual cues. The subject will then use a rotary dial mounted to an armrest to point to the desired target location as quickly and accurately as possible, and then verbally report on their orientation. Vibrotactile feedback will be used during some parabolas to provide cueing of the direction of the floor.

RESULTS & DISCUSSION

During tilt-translation adaptation with the GIF-aligned paradigm, motion sickness symptoms were greatest at 0.15 Hz with only 3 of 14 being able to complete the full 30 min protocol. Seven of 14 were able to complete 0.3 Hz during passive pitch tilt and 13 of 14 completed 0.6 Hz. There were no significant differences between pitch versus roll or between active versus passive stimulus modes at 0.3 Hz. Changes in spatial cognitive performance using a “match to rotated sample” paradigm were also greatest at the lowest frequency. The ability to control tilt orientation was improved by vibrotactile feedback, especially at low frequencies and/or in the presence of conflicting translation cues. Our results to date support our hypothesis that the central nervous system utilizes both multi-sensory integration and frequency segregation as neural strategies to resolve the ambiguity of tilt and translation stimuli. The TSAS results are promising in that a fairly simple sensory aid may prove useful to significantly improve control performance of acceleration platforms when attempting to maintain orientation within a limited tilt range.

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